TECHNICAL NOTE

Prevention of air travel–related deep venous thrombosis with mechanical devices: Active foot movements produce similar hemodynamic effects

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Objective: **We compared the hemodynamic effects of different mechanical devices aimed for prevention of travel-related deep venous thrombosis with active foot movements.**

Methods: **Two battery-operated intermittent pneumatic compression (IPC) devices and three foot and calf muscle pump facilitating devices (PFD) that claimed to prevent travel-related deep venous thrombosis were tested in 17 healthy volunteers on the ground and in 8 of same volunteers during flight. Flow changes during active foot movements were compared with the effects of each of the tested devices.**

Results: **There was no significant difference in hemodynamic effect between PFDs and active foot movements. The hemodynamic effects of IPC devices were significantly less compared with active foot movements. Values obtained during air flights were not significantly different from those obtained on the ground.**

Conclusions: **Whereas IPC use for prevention of venous stasis during flight can be justified for immobile patients or during sleep, PFDs do not provide additional hemodynamic benefits compared with simple movements of the foot. (J Vasc Surg 2006;44:889-91.)**

The existence and magnitude of association between prolonged air travel and venous thromboembolism have been studied and debated for the last three decades.[1,2] Prevention of venous thromboembolism events in air travelers is an even more complicated issue that requires an understanding of hemodynamic, hematologic, and environmental mechanisms of thrombogenesis during flight. Use of elastic compression and low-molecular-weight heparin has been shown to be effective in the prevention of subclinical deep venous thrombosis (DVT),[3,4] and intermittent pneumatic compression (IPC) has been suggested as a preventive measure.[5]

Several recent episodes of fatal pulmonary embolism after long air travel were widely publicized by the media.[6-8] Public attention to this issue has created educational opportunities, but it has also provided a fertile commercial environment for products aimed at DVT prevention. One class of such products, known as foot exercisers or calf muscle pump facilitating devices (PFD), has been extensively advertised via the Internet (eg, http://www.lymgym.com, http://www.preventproducts.com, http://www.arjan.com, http://www.dvthealth.co.uk, and http://www.airogym.com). The usual claims made are that these devices facilitate calf muscle pump function and prevent DVT by increasing the venous flow. Although limited data supporting these claims are available on some of the Web pages, we could not find related publications in peer-reviewed sources.

The purpose of this study was to investigate the hemodynamic effects of two groups of mechanical devices aimed at prevention of travel-related DVT: IPC and PFD. Changes in venous flow produced by active foot movements were chosen as a reference point to answer the question of whether any of the studied devices produces an increase in venous flow superior to that caused by foot movements. We attempted to study these effects during air flights and on the ground.

METHODS

The study protocol was approved by the Institutional Review Board of Hawaii Pacific Health, and written informed consent was obtained from all participants. Seventeen healthy volunteers were recruited to participate in this study. The average age was 43.6 years (range, 19-65 years); there were eight women and nine men. Participants had no history of heart disease, peripheral arterial disease, diabetes, musculoskeletal disorders, or lymphedema. None of the participants had a history of acute or chronic venous disease, unilateral leg edema, or previous vascular operations. Each of the volunteers underwent a detailed venous duplex ultrasound scan and ankle-brachial index measurement before inclusion in the study to confirm the absence of vascular abnormalities.

Each volunteer was examined in our vascular laboratory. In addition, 8 of the 17 volunteers were examined during air flights from Hawaii to the mainland United States from June to October 2002. In-flight testing was performed within 48 hours from examination in the vascu-

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lar laboratory. In November 2002, airport security restrictions made it unfeasible to complete in-flight testing on the remaining nine volunteers.

A portable ultrasound scanner (Sonosite 180 Plus with an L38/10-5 MHz 38-mm linear array transducer; SonoSite, Inc, Bothell, Wash) was used for all scans. Duplex scans were performed with subjects sitting in a chair; all measurements were performed at the proximal segment of the popliteal vein of one randomly selected extremity. When subjects were tested on the ground, their position was modeled after the seat configuration of economy class seats. Although the office chair was used, its width was 46 cm (United Airlines seats are 45.7 cm; Delta airlines seats are 46 cm), the distance between the chair and the wall was set at 80 cm (United Airlines' pitch is 78.7 cm; Delta airlines' pitch is 81 cm), and the back of the chair was angled at 20°, which is similar to most airlines' seat configurations.

The mean peak velocity (MPV), velocity time integral (VTI), and diameter of the vein were measured. The MPV increase was calculated as the difference between MPV when a device was used and MPV at baseline divided by MPV at baseline. The volume flow increase was calculated as a ratio of VTI when a device was used and VTI at baseline. It has been shown previously that changes in vein diameter closely correlate with changes in flow velocity[9]; therefore, when used for the same vein in the same individual, VTI ratios are equal to volume flow ratios.

Before the test, volunteers were instructed in and had practiced performing foot movements and using PFDs uniformly. After baseline measurements, participants were asked to perform three foot movements (dorsal flexion followed by plantar flexion) with 1-minute intervals between movements. After flow velocities returned to the baseline level, other devices were tested in random order. Flow velocities were recorded during three cycles for each of the tested devices with one cycle per second. Velocities were allowed to return to the baseline level before the next device was tested. A contralateral extremity was used as a control to identify whether any changes in venous flow occurred during the test. All measurements and calculations were performed on recorded images by a technologist blinded to which image corresponded to which device, except for baseline measurements.

Devices

Three foot and calf muscle PFDs that claimed to prevent travel-related DVT were selected: Ankle Pumper Assist (Prevent Products, Inc, Mendota Heights, Minn), LymGym (Lymgym Ltd, Woodbridge, UK), and U-SIT (Fordena Pty, Ltd, Chatswood, NSW, Australia). The selected devices represent three groups of foot exercisers. Ankle Pumper Assist provides foot support for dorsal and plantar flexions, LymGym combines this support with passive movement of the contralateral foot, and U-SIT applies pressure against plantar venous plexus while the patient performs dorsal flexion (Fig 1).

Two battery-powered IPC devices were tested: WizAir (Medical Compression Systems Inc, Ltd, Or-Akiva, Israel) and Travel Air 8-Prototipe (ACI Medical, Inc, San Marcos, Calif). The size, weight, and battery life of these devices made them suitable for use during air flights. Only calf sleeve garments were used for this study. Both devices had similar compression profiles. Pressure in the garment was controlled against the air pressure around the unit, so changes in the air pressure in the cabin during flight did not affect the relative pressure inside the garment.

Table I. Mean peak velocities (MPVs) at baseline, during foot movements, and during use of the tested devices on the ground (n = 17)

	MPV		P *(paired* t *test)*	
*Variable**	*Mean*	*SD*	*Vs baseline*	*Vs foot movements*
Baseline	6.23	1.92	NS	<.0001
Foot movements	28.48	3.87	<.0001	NS
IPC1	20.75	0.94	<.0001	<.0001
IPC2	21.04	1.19	<.0001	<.0001
PFD1	28.56	3.79	<.0001	.82
PFD2	28.62	3.48	<.0001	.63
PFD3	28.56	4.39	<.0001	.9

IPC, Intermittent pneumatic compression; *PFD,* pump facilitating device.
*IPC1, Wiz Air; IPC2, Travel Air 8-Prototipe; PFD1, Lym Gym; PFD2, Ankle Pumper Assist; PDF3, U-SIT.

Table II. Mean peak velocities (MPVs) and volume flow (VF) increase from the baseline values during foot movements and during use of the tested devices on the ground (n = 17)

	MPV increase			*VF increase*		
*Variable**	*Mean*	*SD*	P *compared with foot movements*	*Mean*	*SD*	P *compared with foot movements*
Foot movement	3.87	1.05	NS	3.67	0.94	NS
IPC1	2.65	1.18	.032	2.59	1.18	.007
IPC2	2.7	1.18	.048	2.62	1.18	.01
PFD1	3.88	1.11	NS	3.71	0.98	NS
PFD2	3.9	1.04	NS	3.92	0.98	.97
PFD3	3.9	1.2	NS	3.91	1.18	.97

*IPC1, Wiz Air; IPC2, Travel Air 8-Prototipe; PDF1, Lym Gym; PDF2, Ankle Pumper Assist; PDF3, U-SIT.

Statistical analysis

Sample size calculation was based on our previous studies of the hemodynamic effects of IPC devices and foot movements.[10] To determine a 10% difference between devices with a power of 80% and a significance level of 5%, 15 participants were needed (SmplePower 2.0 statistical software; SPSS Inc, Chicago, Ill). Because in-flight testing was completed in only eight volunteers, the observed power was calculated and reported when the results of in-flight testing were not significantly different from those of on-ground tests. Descriptive statistics are reported as means and standard deviations. Repeated-measures analysis

Table III. Mean peak velocities (MPVs) at baseline, during foot movements, and during use of the tested devices on the ground and during flight (n = 8)

	MPV on the ground		*MPV during flight*		
*Variable**	*Mean*	*SD*	*Mean*	*SD*	*P value*
Baseline	6.23	1.92	5.69	1.66	.15
Foot movements	28.48	3.87	24.5	5.93	.19
IPC1	20.75	0.94	18.93	3.84	.24
IPC2	21.04	1.19	18.9	4.13	.24
PFD1	28.56	3.79	24.9	6.36	.17
PFD2	28.62	3.48	24.45	6.46	.15
PFD3	28.56	4.39	24.14	6.26	.19

*IPC1, Wiz Air; IPC2, Travel Air 8-Prototipe; PDF1, Lym Gym; PDF2, Ankle Pumper Assist; PDF3, U-SIT.

Fig 1. Muscle pump facilitating devices.

was used either as a paired *t* test or a generalized linear model when appropriate. Bonferroni adjustment for multiple comparisons was used for comparison between multiple devices. The level of statistical significance was set at $P > .05$. SPSS 14.0 statistical software was used for all calculations (SPSS Inc).

RESULTS

When tested on the ground, active foot movements produced an MPV increase from 6.2 ± 1.9 cm/s (at rest) to 28.5 ± 3.9 cm/s. When PFDs were used, MPVs were almost identical to those with foot movements ($P > .5$; observed power, >0.8). IPC devices produced lesser MPVs than foot movements (Table I). The increase of venous velocities and volume flow relating to the baseline values followed same pattern (Table II). The hemodynamic effect was not significantly different between the two tested IPC devices or among the three PFDs. Values obtained during air flights were not significantly different from those obtained on the ground ($P > .05$; observed power, 0.77) (Table III).

DISCUSSION

Venous stasis is considered one of the major contributors to the development of deep venous thrombi.[11] Because prolonged air travel significantly limits travelers' mobility, measures preventing venous stasis are highly desirable, especially for individuals with an underlying prothrombotic tendency. Although moderate exercise, such as walking around the cabin, may solve this problem for awake and mobile travelers, the limited space of the aircraft restricts such activities, particularly for patients after orthopedic surgeries or those with obesity, who have high risk of DVT.

This study was focused on two groups of mechanical devices that aimed to increase venous outflow from the lower extremities. IPC devices have been widely used for DVT prevention in immobile patients in hospital and nursing home settings. IPC devices selected for this study have features that make it possible to use them during air flight: they are light, small, and battery powered. They do not require active movements and therefore can be used in immobile patients or while passengers are asleep. PFDs do require active foot movements and therefore can be used only in active, awake individuals. This study did not include patients with circulatory problems, in whom tested devices may act differently.

Our findings confirmed that in healthy individuals, all of the tested devices significantly increased venous blood flow velocities and venous volume flow. However, the hemodynamic effect of PFDs was not different from simple movements of the foot, and tested IPC devices produced a lesser hemodynamic effect than foot movements. Our observations during air flights suggest that cabin environment does not influence the hemodynamic effect of tested devices. Although IPC use for prevention of venous stasis during flight can be justified for immobile patients or during sleep, PFDs do not provide additional hemodynamic benefits compared with simple movements of the foot.

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